

## **Rattan (Calamoideae) Diversity and Biomass Change in Different Habitat Types During Two Years**

<sup>1</sup>Nadine Ruppert\*, <sup>1</sup>Asyraf Mansor and <sup>1,2</sup>Shahrul Anuar Mohd Sah

<sup>1</sup>School of Biological Sciences, Universiti Sains Malaysia, 11800 USM, Pulau Pinang, Malaysia

<sup>2</sup>Centre for Marine and Coastal Studies, Universiti Sains Malaysia, 11800 USM, Pulau Pinang, Malaysia

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**Abstrak:** Rotan (subfamily Calamoideae) adalah satu komponen penting dalam hutan paleotropik. Walau bagaimanapun, tidak banyak kajian yang dijalankan berkaitan kelimpahan palma ini, khususnya di Semenanjung Malaysia. Kajian ini bertujuan untuk menilai kepelbagaian rotan, kelimpahan, dan biomassa rotan di dua jenis habitat yang berbeza, iaitu hutan dipterokarpa dan paya air tawar di dalam Hutan Simpan Segari Melintang, Perak selama tempoh dua tahun. Semua batang rotan dalam lima plot kajian (A–E) berukuran 100 × 100 m setiap satu di kedua-dua jenis habitat telah dikira pada tahun 2011 dan 2013 dan indeks kepelbagaian Shannon-Wiener ( $H'$ ) dan indeks ketidak samaan Bray-Curtis turut dikira. Sebanyak 11 spesies dari 5 genera (161 batang  $ha^{-1}$ ) telah disampel. Kelimpahan rotan adalah lebih tinggi di plot kawasan berpayau, bagaimanapun, kepelbagaian rotan ( $H'$ ) adalah paling tinggi dalam kawasan dipterokarpa plot D:  $H'_{(2011)}1.79$ ;  $H'_{(2013)}1.84$ . Indeks-indeks Bray-Curtis bagi kelimpahan (persamaan tertinggi di paya air tawar: plot-plot BC<sub>(2011)</sub> 0.484, BC<sub>(2013)</sub> 0.262) dan biomassa adalah tertinggi bagi plot kajian dengan jenis tumbuh-tumbuhan yang sama untuk kedua-dua tahun. Bagi biomassa rotan, pasangan plot paling serupa berubah dari tahun ke tahun: plot-plot dipterokarpa A dan D adalah paling serupa bagi tahun 2011 (0.509), plot-plot berpayau B dan C adalah paling serupa bagi tahun 2013 (0.282). Kajian ini dapat membantu dalam menyumbang maklumat kepada taburan spesies rotan tempatan di hutan hujan primer Semenanjung Malaysia.

**Kata kunci:** *Arecaceae*, *Calamus*, *Ceratolobus*, *Daemonorops*, *Korthalsia*, Palma, Rotan

**Abstract:** Rattans (subfamily Calamoideae) are an important component of the forests of the Old World. However, few studies have been conducted on the distribution of these abundant palms within different habitats, specifically in Peninsular Malaysia. This study was aimed at assessing rattan diversity, abundance and biomass change across two different habitat types, namely, dipterocarp forests and fresh-water swamps within the Segari Melintang Forest Reserve, Perak, within two years. All rattan stems within five 100 m × 100 m sized study plots (A–E) of the two habitat types were counted in 2011 and 2013, and Shannon-Wiener diversity indices ( $H'$ ) and Bray-Curtis dissimilarity indices were calculated. A total of 11 species from 5 genera (161 stems  $ha^{-1}$ ) were sampled. Rattan abundance was higher in all swamp plots; however, rattan diversity ( $H'$ ) was highest in the dipterocarp plot (D:  $H'_{(2011)}1.79$ ;  $H'_{(2013)}1.84$ ). Bray-Curtis indices of rattan abundance

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\*Corresponding author: [n.ruppert@usm.my](mailto:n.ruppert@usm.my)

(highest similarity in swamp: plot BC<sub>(2011)</sub> 0.484, BC<sub>(2013)</sub> 0.262) and biomass were highest for study plots with the same vegetation types in both years. For rattan biomass, the most similar plot pairs changed during the years: dipterocarp plots A and D were most similar in 2011 (0.509), and swamp plots B and C were most similar in 2013 (0.282). This study helped contribute information regarding the distribution and dynamics of rattans in a primary rainforest of Peninsular Malaysia.

**Keywords:** *Arecaceae*, *Calamus*, *Ceratolobus*, *Daemonorops*, *Korthalsia*, Palms

## INTRODUCTION

Rattan palms (family *Arecaceae*, subfamily *Calamoideae*) are an important component of the primary and secondary forest vegetation of South-East Asia because they contribute structural complexity (Putz 1991), shelter (e.g., Sunderland 2004), and food (e.g., Henderson 1986; Lee 1995; Sunderland & Dransfield 2002; Kidyoo & McKey 2012). Rattans are comprised of approximately 600 species of 13 genera and grow throughout the Old World tropics and subtropics of Australia, Asia, and Africa (Dransfield *et al.* 2008). They reach their highest diversity in the Western part of Malaysia, where endemic species can occur together with as many as 30 species existing in one locality, thus helping to shape the distinctive local forest vegetation (Dransfield & Manokaran 1994). In Peninsular Malaysia, 106 species can be found, and half of these species are endemic (Dransfield 1979). All rattans are spiny and share common fruit characteristics, i.e., overlapping scales on the fruits (Dransfield 1992). Rattans are used as a commercial commodity on a global scale as well as for local purposes and have become the most important non-timber forest product in South-East Asia (Ros-Tonen 2000; FAO 2010). Although there were some attempts to establish commercial rattan plantations in the region during the last 30 years (e.g., Supardi & Wan Razali 1989), rattan is still mainly collected from the wild, mostly illegally (Siebert 2001). Rattan has become threatened with overexploitation through unsustainable harvesting methods during past decades (Sunderland & Dransfield 2002). Local communities that depend on rattan as a source of income are economically affected by the loss of rattan abundance and diversity (Avé 1988).

Although rattans are an important component of Malaysian forests (Dransfield *et al.* 2000), few studies were conducted with respect to rattan diversity in local forests (e.g., Tan *et al.* 1990; Supardi *et al.* 1998; Supardi 1999; Nur Hasmiza & Mohd Nazip 2011).

Here, we assessed rattan diversity and biomass in a lowland coastal rainforest in Perak across two different forest types (swamp vs. dipterocarp) and during two years (2011 and 2013). Moreover, we tested for a possible difference in rattan species richness between the forest edge and centre. Within lowland forests, rattan species are specific for different habitat types (Dransfield 1979); thus, we expected differences in species abundance and the contribution of biomass for dipterocarp forests or alluvial fresh-water swamp forests at the study site.

## MATERIALS AND METHODS

### Study Site

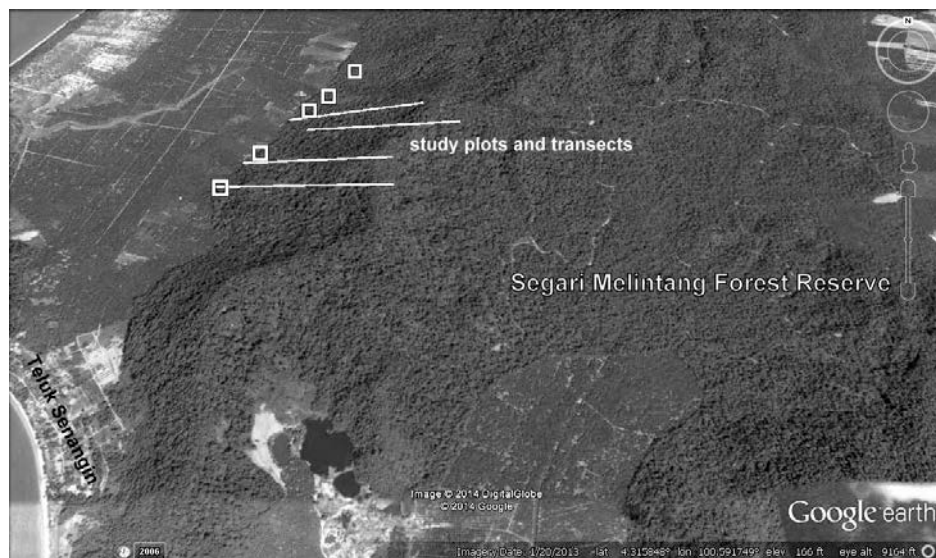
The study site was located at the Segari Melintang Forest Reserve, Perak, near the village of Teluk Senangin (Fig. 1). Its main vegetation type is lowland dipterocarp forest, and there are patches of alluvial fresh-water swamp along its edges. The reserve currently comprises 2742 ha, of which 407 ha is strictly protected virgin jungle reserve (VJR) (Perak Forestry Department, pers. comm.). A more detailed description of the study site can also be found in Ruppert (2014).



**Figure 1:** Location of the Segari Melintang Forest Reserve, Perak, Peninsular Malaysia.  
*Note:* Map courtesy of Rahmad Zakaria.

Five permanent study plots (termed A–E from south to north, each 100 × 100 m) near the forest edge were established for a long-term rattan survey. The study plots were chosen to cover both vegetation types (dipterocarp forest and freshwater swamp). Plots A and D were dominated by mesic, firm podsolc and lateritic soils (Panton 1970) and by dipterocarp species, with a high abundance of *Eugeissonia tristis* palms in some areas. Both plots ran up a steep hill slope up to 40 m a.s.l. Plots B, C, and E consisted of gley soils (Panton 1970) and freshwater swamp vegetation (mainly *Salacca* spp.), with elevations less than 10 m a.s.l. The boundaries of any two neighbouring plots were at least 50 m apart from each other, and the distance between the outermost plots (A and E) was approximately 1.5 km.

In addition to the five permanent study plots, four transects (each 900 × 20 m) near plots A, B, and C (spaced 100 m apart from each other) reached from the forest edge into its centre and stretched up a hill (maximum elevation 150 m a.s.l.). They were sampled once in 2012 to test for differences in the rattan species richness between the forest edge and centre (Fig. 2).



**Figure 2:** Arrangement of five rattan study plots (termed A–E from south to north, 100 × 100 m) and four transect strips (900 × 20 m; true to scale).  
*Note:* Image sourced from Google earth, on 20 January 2013.

### Rattan Assessment

All rattan clumps within the five study plots were counted in January 2011, November 2012, and March 2013 as well as once along those transects in November 2012. Species, sex, number of stems, and GPS position were recorded for each individual clump.

## Rattan Biomass Estimations

A full account of the methods applied to determine the biomass values can be found in Ruppert *et al.* (2016). The rattan biomass of each plot was determined by multiplying the number of stems per species per plot with their respective biomass values (available from Ruppert *et al.* 2016).

## Statistics

The variable of the quantitative data of rattan abundance followed a non-normal distribution for both years (Shapiro-Wilkinson test,  $p < 0.05$ ,  $W_{2011}$  0.748,  $W_{2013}$  0.691). A Kruskal-Wallis test was used to test for differences in rattan abundance and biomass between the plots (inter-plot comparison), while the Wilcoxon-signed rank test was applied to test for differences in rattan abundance and biomass of the same plot between two years (inter-year comparison, e.g., plot  $A_{2011}$  vs.  $A_{2013}$ ). Bray-Curtis dissimilarities were calculated to compare for greater similarities of rattan abundances and biomass between habitat types, i.e., either dipterocarp plots (A and B) or swamp plots (B, C, and E). This index ranged between 0 and 1, where 0 meant the two sites were most similar, and 1 meant the two sites were most dissimilar. A subsequent Mantel test of the two matrices (2011 and 2013) was applied to test for changes of similarity between the two years.

## RESULTS

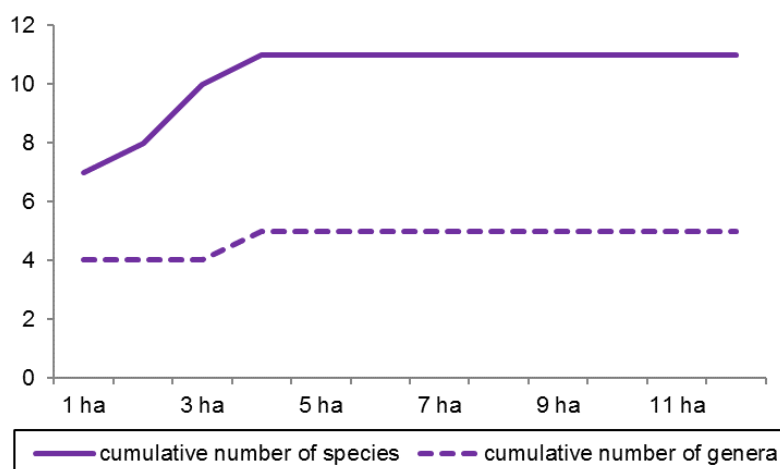
### Rattan Abundance and Diversity

#### Total

A total of 1964 stems were sampled on 12.2 ha within the study plots (Table 1) and along the transect strips in 2012, which resulted in a total rattan abundance of 161 stems per hectare at the Segari Melintang Forest Reserve during that time. Only 9 out of 11 species and 4 out of 5 genera were recorded along the 4 transects that reached into the forest centre. An increase in the sampling area size did not lead to an increase in species or genera number from 4 ha onwards (Fig. 3). Rattan diversity was lowest near the forest edge (0–300 m:  $H'$  0.76–0.83) and highest ( $H'$  1.69) at a distance of 300–450 m away from the forest edge, then lowering again towards the forest centre (450–900 m:  $H'$  1.03–1.22).

**Table 1:** Rattan species composition of five 1 ha-sized plots (A–E) at Segari Melintang Forest Reserve, Perak: stem numbers, relative abundances (%), Shannon-Wiener diversity indices (H'), and evenness (E) of all rattan species per plot in 2011 and 2013.

Species	Plot					Total	%
	A	B	C	D	E		
2011							
<i>Calamus castaneus</i>	4	121	106	3	122	356	23.8
<i>Calamus densiflorus</i>	36	3	7	0	15	61	4.1
<i>Calamus diepenhorstii</i>	21	0	0	6	28	55	3.7
<i>Calamus insignis</i>	6	0	1	5	0	12	0.8
<i>Ceratolobus subangulatus</i>	51	3	4	3	6	67	4.5
<i>Daemonorops angustifolia</i>	0	303	83	0	19	405	27.0
<i>Daemonorops calicarpa</i>	3	3	22	13	59	100	6.7
<i>Daemonorops geniculata</i>	0	3	4	0	5	12	0.8
<i>Daemonorops micracantha</i>	0	4	22	5	267	298	19.9
<i>Korthalsia rigida</i>	10	11	2	9	0	32	2.1
<i>Myrialepis paradoxa</i>	0	0	100	0	0	100	6.7
Total stem number	131	451	351	44	521	1498	100.0
Percentage (%)	8.6	30.1	23.8	2.8	34.7	100.0	
Diversity (H')	1.55	0.88	1.63	1.79	1.41		
Evenness (E)	0.79	0.43	0.71	0.92	0.68		
Species Richness (S)	7	8	10	7	8	11	
2013							
<i>Calamus castaneus</i>	5	132	122	3	151	413	30.3
<i>Calamus densiflorus</i>	37	0	10	0	20	67	4.9
<i>Calamus diepenhorstii</i>	23	0	0	8	33	64	4.7
<i>Calamus insignis</i>	6	0	1	5	0	12	0.9
<i>Ceratolobus subangulatus</i>	68	4	6	4	9	91	6.7
<i>Daemonorops angustifolia</i>	0	147	69	0	29	245	18.0
<i>Daemonorops calicarpa</i>	3	3	17	10	72	105	7.7
<i>Daemonorops geniculata</i>	0	3	6	0	5	14	1.0
<i>Daemonorops micracantha</i>	0	17	28	6	251	302	22.2
<i>Korthalsia rigida</i>	6	4	2	13	0	25	1.8
<i>Myrialepis paradoxa</i>	0	0	25	0	0	25	1.8
Total Stem Number	148	310	286	49	570	1363	100.0
Percentage (%)	10.9	22.7	21.0	3.6	41.8	100.0	
Diversity (H')	1.45	1.07	1.65	1.84	1.51		
Evenness (E)	0.73	0.55	0.72	0.94	0.73		
Species Richness (S)	7	7	10	7	8	11	



**Figure 3:** Rattan species/genera-area accumulation curve for rattans at Segari Melintang Forest Reserve, Perak.

### Study Plots

Shannon diversity indices ( $H'$ ) within the 5 study plots ranged from 0.88 (B, 2011) to 1.78 (D, 2013) ( $H_{\max}$  2.40, Table 1). Plot D hosted only few rattan species and stems, but the stem numbers were evenly distributed across species. The other plots were dominated by a few species, for example *Daemonorops angustifolia* in plot B and *Daemonorops micracantha* in plot E. In general, the rattan species richness was higher in the swamp plots (8–10 species) than in the Dipterocarp plots (7 species), but no plot hosted all 11 rattans species together (Table 1).

There was no significant difference in the rattan abundances between the two years (Kruskall-Wallis test,  $p > 0.05$  for 2011 and 2013) or within one plot between the two years (pair-wise comparison of rattan abundance of one plot between 2011 and 2013, Wilcoxon–signed rank test,  $p > 0.05$  for all plots<sub>2011vs.2013</sub>).

The overall rattan biomass was higher in the swamp plots than in the dipterocarp plots throughout the study period. The highest biomass (in kg) was recorded for plot B<sub>2011</sub> (7501.5 kg), followed by C<sub>2011</sub> (4692.0), B<sub>2013</sub> (4546.2), E<sub>2011</sub> (444.1), E<sub>2013</sub> (3918.7), and C<sub>2013</sub> (3481.0). For the dipterocarp plots, plot A<sub>2011</sub> (518.4) had the highest biomass throughout the study period, followed by A<sub>2013</sub> (504.6), D<sub>2013</sub> (317.0), and D<sub>2011</sub> (263.6) (Table 2).

There was no significant difference in the rattan biomass between the plots in both years (Kruskall-Wallis test,  $p > 0.05$  for 2011 and 2013) or within one plot between the two years (pair-wise comparison of rattan biomass in one plot between 2011 and 2013, Wilcoxon–signed rank test,  $p > 0.05$  for all plots<sub>2011vs.2013</sub>) (see also Ruppert *et al.* 2016).

**Table 2:** Rattan aboveground biomass (kg) per study plot in 2011 and relative biomass changes (2013). Biometric measurements for all mentioned species and additional information can be derived from Ruppert et al. (2016).

Species	Year		Plots					total (kg)	(%)
	Total 2011	A	B	C	D	E			
	Total 2013	504.6	4546.2	3481.0	317.0	4441.7	13290.5		
<i>Calamus castaneus</i>	2011	44.5	1346.4	1179.5	33.4	1357.6	3961.4		
biomass change	2013	+11.1	+122.4	+178.0	0.0	+322.7	+634.3	+16.0	
<i>Calamus densiflorus</i>	2011	205.2	17.1	39.9	0.0	85.5	347.7		
biomass change	2013	+5.7	-17.1	+17.1	0.0	+28.5	+34.2	+9.8	
<i>Calamus diepenhorstii</i>	2011	99.3	0.0	0.0	28.4	132.4	260.2		
biomass change	2013	+9.5	0.0	0.0	+9.5	+23.7	+42.6	+16.4	
<i>Calamus insignis</i>	2011	7.7	0.0	1.3	6.5	0.0	15.5		
biomass change	2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
<i>Ceratolobus subangulatus</i>	2011	27.0	1.6	2.1	1.6	3.2	35.5		
biomass change	2013	+9.0	+0.5	+1.1	+0.5	+1.6	+12.7	+35.8	
<i>Daemonorops angustifolia</i>	2011	0.0	5938.8	1626.8	0.0	372.4	7938.0		
biomass change	2013	0.0	-3057.6	-274.4	0.0	+196.0	-3136.0	-39.5	
<i>Daemonorops calicarpa</i>	2011	12.0	12.0	87.7	51.8	235.2	398.6		
biomass change	2013	0.0	0.0	-19.9	-12.0	+51.8	+19.9	+5.0	
<i>Daemonorops geniculata</i>	2011	0.0	25.4	33.9	0.0	42.4	101.6		
biomass change	2013	0.0	0.0	+16.9	0.0	0.0	+16.9	+16.7	
<i>Daemonorops micracantha</i>	2011	0.0	25.3	139.3	31.7	1690.1	1886.3		
biomass change	2013	0.0	+82.3	+38.0	+6.3	-101.3	+25.3	+1.3	
<i>Korthalsia rigida</i>	2011	122.6	134.9	24.5	110.3	0.0	392.3		
biomass change	2013	-49.0	-85.8	0.0	+49.0	0.0	-85.8	-21.9	
<i>Myrialepis paradoxa</i>	2011	0.0	0.0	1557.0	0.0	0.0	1557.0		
biomass change	2013	0.0	0.0	-1167.8	0.0	0.0	-1167.8	-75.0	

### Habitat Comparison

Bray-Curtis dissimilarities for rattan abundance and biomass between habitat types (plot A and D: dipterocarp forest; plot B, C, and E: alluvial fresh-water swamp forest) in 2011 and 2013 are shown in Table 3. Plots of the same habitat type were more similar in rattan abundance and biomass to each other than to plots of the other habitat type. There were no significant changes in (dis-)similarity between the two years for rattan abundance (Mantel test,  $r(AB)$  0.973,  $p < 0.001$ , significant matrix correlation) and biomass (Mantel test,  $r(AB)$  0.938,  $p < 0.0045$ , significant matrix correlation).



**Table 3:** Bray-Curtis dissimilarities of rattan abundance and biomass between two habitat types: Plots A, D: lowland dipterocarp forest; and Plots B, C, D: alluvial fresh-water swamp forest. BC = 0: most similar, and BC = 1: most dissimilar. Similar plots are marked in grey.

Year	Plot	Rattan abundance					Rattan biomass				
		A	B	C	D	E	A	B	C	D	E
2011	A	–	0.921	0.913	0.669	0.849	–	0.951	0.952	0.509	0.890
	B	0.921	–	0.484	0.911	0.678	0.951	–	0.522	0.953	0.685
	C	0.913	0.484	–	0.863	0.578	0.952	0.522	–	0.942	0.569
	D	0.669	0.911	0.863	–	0.893	0.509	0.953	0.942	–	0.930
	E	0.849	0.678	0.578	0.893	–	0.890	0.685	0.569	0.930	–
2013	A	–	0.930	0.876	0.706	0.833	–	0.953	0.923	0.598	0.881
	B	0.930	–	0.262	0.889	0.573	0.953	–	0.282	0.945	0.514
	C	0.876	0.262	–	0.845	0.493	0.923	0.282	–	0.927	0.426
	D	0.706	0.889	0.845	–	0.900	0.598	0.945	0.927	–	0.936
	E	0.833	0.573	0.493	0.900	–	0.881	0.514	0.426	0.936	–

## DISCUSSION

### Abundance, Diversity, and Biomass

The species-areas accumulation curve showed no increase in species richness from 4 ha onwards, and no new species were found along the transects that reached into the forest centre. Therefore, the sampling plots at the forest edge represented the general rattan species profile of this (southern) part of the Segari Melintang Forest Reserve. However, during a random survey walk in another part of the Segari Melintang Forest Reserve, which was approximately 2 km North of the study plots, the authors discovered several clumps of *Korthalsia flagellaris*. This species is commonly associated with swampy forests (Dransfield 1979) and was not found within the study plots or along the sampling transects. Therefore, more sampling transects distributed over a wider range of the whole reserve, especially within the lower lying areas, are recommended to accurately assess the rattan species profile of the Segari Melintang Forest Reserve. While statements made by Dransfield (1979, 1992) were deduced from his years of observation walking through many forest types, these statements need to be supported by results from more studies on the matter. Hence, it would also be important to record environmental gradients along the transects or within plots per 20 × 20 m at the Segari Melintang Forest Reserve to gain a more complete picture. These should also be made for the average tree stand density (trees above 10 cm diameter) to indicate the relative light intensity and ground undergrowth that may be related to the abundance of certain rattan species.

Our study site had a rather low species diversity compared to other published studies in lowland forests of Peninsular Malaysia (e.g., Supardi *et al.* 1998; Supardi 1999; Nur Hasmiza & Mohd Nazip 2011). Nevertheless, the highest variety of genera was found here. The highest species diversity was

recorded 300–450 m into the forest, and it was lower towards the forest edge and centre. The forest centre itself was situated on a hill top, and its ecological features (e.g., poorly drained soils and low canopy density) may have excluded some rattan species from this habitat type (Dransfield 1992). This may have led to an overall lower diversity than that found on the gentle slopes reaching up the hill towards the forest centre. At the forest edge, only two species, *Calamus castaneus* and *D. angustifolia*, contributed to high stem numbers. Moreover, *D. angustifolia* could not be sampled any deeper than 100 m in the forest. Here, this species was associated with disturbed areas with open canopy and represented by high stem numbers along the forest edge (Dransfield 1979, p. 19).

*C. castaneus* and *D. micracantha* were found in high abundance in the swamp plots, and *D. angustifolia* and *Daemonorops geniculata* were solely confined to this habitat type. *Calamus diepenhorstii* was found in higher abundance at the dipterocarp forest sites, and although abundant in plot E, clumps here were restricted to a few elevated patches of dry soil within the plot. *Calamus insignis* was most abundant in the dipterocarp habitat; only one individual in rosette form was discovered in swamp plot C, again on a slightly elevated dry soil patch at the edge of the plot. There was no significant change in the similarities of rattan abundance and biomass between the plots in 2011 and 2013, although some species, such as *Myrialepis paradoxa* and *D. angustifolia*, with the highest individual biomasses, lost 50%–75% of their stems during the study period due to natural causes (unidentified disease) and occasional illegal harvest (*D. angustifolia*) (see also Ruppert et al. 2016).

### Habitat Comparison

Plots with similar habitat structure (A and D: dipterocarp forest; B, C, and E: swamp forest) were more similar in rattan abundance and biomass in both years compared to plots of the other habitat type. In both years, the plots with the most similar rattan abundance were B and C (both swamp). For rattan biomass, the similarity changed between the years, from A and D (both dipterocarp forest) being most similar in 2011 and C and B being most similar in 2013.

Rattans can utilise a wide range of ecological conditions; however, some species are restricted to specific habitat types (Dransfield et al. 2008). *C. castaneus* and *D. micracantha* were found in high abundance in the swamp plots, and *D. angustifolia* and *D. geniculata* were solely confined to this habitat type. *C. diepenhorstii* was found in higher abundance at the dipterocarp forest sites, and although abundant in plot E, clumps here were restricted to a few elevated patches of dry soil within the plot. *C. insignis* was most abundant in the dipterocarp sites; only one juvenile individual was discovered in the swamp plot C, again on a slightly elevated dry soil patch at the edge of the plot. There were no significant changes in the similarities of rattan abundance and biomass between the plots in 2011 and 2013, although some species, such as *M. paradoxa*, was confined to one single spot with open canopy at a well-drained area in the swamp plot C. *Daemonorops densiflorus* was found in both habitat types, although Dransfield (1979) attributed this species to dry hilly areas.

## CONCLUSION

This study helped add more information to the field of rattan research that should still be complemented by studies in other forests of Peninsular Malaysia to learn more about the diversity of Malaysian rattans across different habitat types. Over the long-term, this knowledge can aid in working towards conservation strategies for this threatened plant family and its habitat.

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